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The many facets of passive design are spelled out in a series of design choices. Starting with the surrounding elements and their effects on the building's energy uses, the procedure moves inward through the envelope, finally considering the thermal dynamics of the structure and its construction materials.

1. DIRECTIONS AND DEFINITIONS

To clear the air and delineate the direction the paper will take, we need to spell out and agree on just what we mean by passive solar heating. My authorities for these definitions are the Dean of Solar Scientists, John Yellott, and one of the most successful advocates of passive solar heating and natural (not solar) cooling of homes and buildings, Harold Hay. It is important to note that the terms active and passive are not mutually exclusive when applied to solar heating systems.

The following are informal quotes from John Yellott.

"A passive solar system utilizes the sun's radiant energy for heating and natural processes for cooling, with only negligibly small requirements for non-renewable energy.

"An active solar system utilizes the sun's radiant energy and nocturnal cooling processes, with the aid of pumps and fans to circulate the fluids used in the required processes."

Harold Hay's definitions of active and passive solar systems are similar, with the distinction being made "on the basis of whether or not the thermal transfer is direct or indirect," i.e., passive systems will utilize the sun's energy directly, and the active systems will include any requiring pumps and other energy consuming device. In addition, Mr. Hay's definition applies the term passive to the many architectural design approaches which not only maximize the sun's advantages in winter heating, but also exclude the sun's undesirable effects in the summer overheating of the structure.

Mr. Hay is one of the first solar designers who emphasizes this principle of duality in solar design of structures.

The antithesis of this common sense design approach for solar heating when you need it is termed the "hardware-happy" approach. This all-too-common, simplistic approach neglects the duality principle and begins with the assumption that step one is to cover the roof with collectors. The remaining steps are usually the additions of piping, pumps, heat exchangers, tanks, automatic controls, and other miscellaneous hardware, all of which are seemingly required to make the system work. For this type system, the public is not being told about the short life of some of the most expensive components. The laws of corrosion still apply. An interesting question for some of the liquid systems is this: What happens during a brownout or blackout?

2. THE PASSIVE APPROACH

In the same sense that providing winter comfort by gas, oil, or electric heat does not require a new, nationwide hardware industry to produce gas heaters, oil heaters, or electric heaters, most of the technology for successful solar heating already exists and most of the hardware needed for a passive or active solar system is available now as off-the-shelf items or can be fabricated on-site by skilled labor or do-it-yourself homeowners.

The passive design described in this paper will not be the purist type which considers the use of any hardware as a contamination of passive principles, but instead will emphasize the architectural and environmental aspects, viewing the solar design problem from the year-around viewpoint, rather than just the winter heating problem. The procedure will start with the environing, natural elements, move inward through the envelope of the structure, then consider the thermal resistances, heat capacities and time lags of the structure and interior masses. Once this has been done, and done properly, the input areas for solar heating can reduce down to about <u>20 percent</u> of the floor area of the structure!

The resulting solar heating systems will qualify as passive in that they will make minimal use of externally powered fluid moving devices and can be fail safe. (A fail-safe system can continue to provide comfort during power failures.) In some cases, the solar heating system can provide 100% of the winter heating load without any use of externally supplied, non-renewable energy.

3. TAKING ADVANTAGE OF THE ENVIRONING ELEMENTS

	Element	Passive Design Function
(a)	Earth, stone	Heat sink, heat source, heat storage medium, insulator, thermal lag damper
(b)	Water	Evaporative cooling, heat storage, heat and mass transfer
(c)	Air, wind	Convective cooling, ventilation, stack effect
(d)	Sky	Nocturnal cooling via radiation to space, diffuse lighting, diffuse solar energy
(e)	Sun	Radiation heating (and overheating), (nature's structures do not overheat), drive for the stack effect, produces wind energy
(f)	Fire	Supplemental heating

4. DUALITY CONSIDERATIONS

"An inevitable dualism bisects nature, so that each thing is a half, and suggests another thing to make it whole; . . . odd, even; subjective, objective; . . . polarity; action, reaction; heat, cold, etc." Ref. (1). Adapting this powerful principle to passive solar design, we must consider solar energy as a boon in the winter and as a bane in the summer. The year-around designs should admit solar energy when needed and reject it when not needed in summer.

In another sense, the best passive designs will consider the problem as a divergent problem, as opposed to convergent, simplistic, plug-in type problems and their machine solutions. Most real life problems are of the divergent type and will involve trade-offs in the approach to their solutions. The all-too-common convergent type solutions require very little thought and usually neglect the duality principle. Ref. (2) gives a useful exposition of divergent-convergent problem solving.

5. HARMONY WITH THE ENVIRONING ELEMENTS

5.1 EARTH CONTACT.

Starting from the ground upward, parts of the structure in thermal contact with the earth can use this storage media-insulator to modify effects of outdoor diurnal temperature swings, reducing the heating load in the winter and reducing or eliminating the usual summer cooling load. For the portions of the structure above ground level, earth berms brought up to window and other non-south openings will amplify the moderating effect on heating and cooling loads.

The ultimate in this direction is reached when all the non-south walls and the roof are covered with earth. With only minimal south window solar input, the interior comfort is maintained with negligible auxilary heating, even when there is no solar input. Typical earth temperatures just outside the perimeter walls approach 65°F the year around if the house interior is heated in winter. The beneficial properties of earth-contact designs assumes that soil moisture content is maintained between reasonable limits.

5.2 WATER BENEFITS

For the solar heated structure, water is still proving to be the most efficient thermal storage medium with its higher specific heat, density, and fluid characteristics. On the negative side, with or without antifreeze, there will be corrosion problems in all devices where water, air, and metal contact each other. In passive solar water heaters, gravity flow can be used to circulate fluid from collector to tank.

5.3 AIR SYSTEMS

Both the water systems and air systems have their gurus and disciples. Each type has its advantages and disadvantages. Thus, the best passive designs will consider the dual nature of either media.

The air system has no freeze problems, but the low density and low heat capacity requires larger, well-designed ducts and fans to move air from collector to storage and to living space. The need for larger horsepower fans would disqualify most current solar air-heating systems as being not passive.

5.4 THE SUN IN PASSIVE DESIGN

From the sun's viewpoint, it matters little whether the intercepting system is active or passive. It is only when the sun's rays start to penetrate the building's envelope that differences become significant. The typical, active, rooftop collector will, with moderate or low efficiency, convert the sun's radiation into heat within the thin confines of the collector enclosure. The laws of radiation, re-radiation, convection, and conduction apply in the enclosure and during the subsequent mass transfer of the heated fluid into the structure via pipes or ducts with their typical heat losses. In contrast to the above approach, most of the successful passive solar heating systems convey the sun's radiation through the building's envelope, then, within the envelope, convert the radiation into space heat, or into MCΔT energy in storage, with no loss of space heat during the process, and with a dispatch, economy, and efficiency in no way possible with the hackneyed, 1949 style, antique collectors currently being touted in the popular press.

5.4.1 The Wright Approach

One of the simplest, most direct approaches is that of architect Wright in New Mexico. All his passive designs use south facing glass for solar input, and use massive walls and floors for heat storage, along with movable insulation for windows at night. At elevations where the winter heating degree-days exceed 7000, several of Wright's houses have provided 80 to 100 percent of the winter heat load by solar means.

5.4.2 Hay's Skytherm System

Harold Hay's unique passive design is being tested in the Dakotas, after several years of satisfactory performance in Phoenix and Atascadero, California. This supreme example of duality applied to the fully passive system operates by the in-phase use of movable insulation over an in-the-ceiling liquid thermal storage. Hay has achieved the world's first working example of the solar heated, naturally (not solar) cooled house. His system provides 100 percent of the winter heating load and all the summer cooling without the use of any input from non-renewable fuels.

5.4.3 The Thomason Solaris System

Another solar heating system which has gained 17 years of operating experience is Harry Thomason's Solaris design, of which 6 examples are in the Washington, D.C., area, and many more around the nation. Although some hardware is used in this design, there are several clever advantages unique to this design. It is low cost, freeze and corrosion proof, and essentially fail-safe. The system can be applied on properly oriented homes or buildings by the average do-it-yourselfer, and is therefore treated with contempt or ignored by the establishment, i.e., the hardware promoters. The simple, straight-forward nature of the Solaris and the Skytherm designs are the results of much "engineering" and divergent thinking by their experienced designers. Thomason's system rates as passive because it operates with only one-quarter horsepower pump during the sunlit hours. Several examples are described in Ref. (3) along with over 200 other passive and active solar heated buildings around the world.

6. AVOIDING THE SUN IN THE SUMMER

Applying the duality principle to year-around solar design implies that summer overheating effects are just as important in our considerations as are the winter heating effects. A comparison of the winter and summer electric generation loads of any utility will confirm this.

The passive design approach should, consequently, provide summer shading of collection areas and for any other transparent opening in the envelope of the building. Using the hourly and monthly values of sun angles, Ref. (4), it is possible to design fins, visors, and overhangs on the outside of the building so that they are seasonally selective, i.e., they can shade openings in the summer and still admit solar radiation in the winter, even though they are fixed in place.

7. EFFICIENT SUPPLEMENTAL HEATING

Now that we have considered all the surrounding elements and their role in passive design, the one remaining element, fire, and its efficient use, need attention. This is especially true when designing the thermal properties of the building's envelope. In the primitive state of our current building knowledge, most of our commercial buildings are <u>losers</u>, along with most of our homes. After all of the conventional winterization measures have been applied to a typical house, it will still leak 40 to 50 percent of its expensive heat out through the windows and doors by conduction, in addition to infiltration losses. Note that this occurs with all storm windows and storm doors in place! Our best commercial buildings have an overall R factor that seldom exceeds 2 or 3. It does not make sense to invest in expensive, oversized heating equipment, solar collectors or otherwise, for the sole purpose of pumping more heat out the windows.

The remedy for this window loss problem is simple and very cost effective, but may require a minor change in our hide-bound life style. Some of the "under developed" countries in Europe have known the solution for centuries. They simply use moveable insulation to seal off the windows at night. Our feeble attempts to do this with drapes only accent the losses. Insulating shutters can increase the R value up to 10 and 15 for windows. For excellent solutions to the window problem, see Refs. (5) and (6).

8. STRUCTURAL THERMAL STORAGE

Most of our current publications and texts on heat loads, insulating, air conditioning, etc. omit one very important property. The forgotten or omitted property is the heat capacity of the various building materials. When the total mass of the interior parts and their respective specific heats are known, the overall interior heat capacity of the structure can be calculated. Along with this, the overall R factor for the building envelope can be figured. When both these are known, the product of the two factors will be the building TIME CONSTANT (RC). Knowledge of the little known RC can furnish the warm-up or cool-down time for the particular structure along with some major energy saving tricks. One result is that we find that the insulation should be on the outer side of the wall instead of the inside.

The structure's RC is an especially important consideration when the intermittent nature of solar energy is involved. Along with the RC value for the interior, it is important to know the thermal time lags of the sunlit walls. With good passive solar design, the time lag can be controlled so that maximum heat transfer through building masses arrives in-phase with maximum space heating needs at night. A good example is the Trombe wall, where the lag is a full 12 hours. Ref. (7) quantifies this thermal lag principle.

Most of the successful, passively solar-heated houses known today have employed massive floors, walls or other interior storage devices to modulate the otherwise very high temperature swings during insulation peaks, storing and recycling the heat back into the adjacent space during the night hours or during the cloudy winter days.

9. SUMMARY

It becomes apparent, when all the energy efficient, passive design steps are considered, that our perspective on the solar heating role changes. There are several design measures which will yield as much, or more energy savings as will the solar input!

Passive design is an art which calls on many disciplines for its answers. It is a diverse problem, and a metaphysical, human problem, not capable of direct, machine, computerized solution, although each of the mechanical inputs can speed up and aid the human designer who must make the final choices.

Passive design is also an old art, and has been taking advantage of the sun's heat and path for all times in the past. When we study examples of past and modern examples of indigenous dwellings, and how well they served, we can only conclude that we have much to re-learn.

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11. BIOGRAPHY

Gordon Moore arrived unexpectedly in Independence, Missouri, about 6 decades ago. He earned his B.Sc. at the University of Missouri-Columbia in 1949. He was at the University of Florida during 1964-67 when he received his Ph.D. As founder of the Missouri Solar Energy Associates, he has seen this grow to a statewide membership exceeding 400 with active chapters in St. Louis. Kansas City, Springfield, and Columbia. Professor Moore is currently teaching courses in Building Design For Low Energy Use to architects and engineers in Kansas City and in St. Louis. He classifies himself as a typical, show-me renegade, definitely non-establishment.